Digital Protection of Power System
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Lecture 03
Components of Digital Relays

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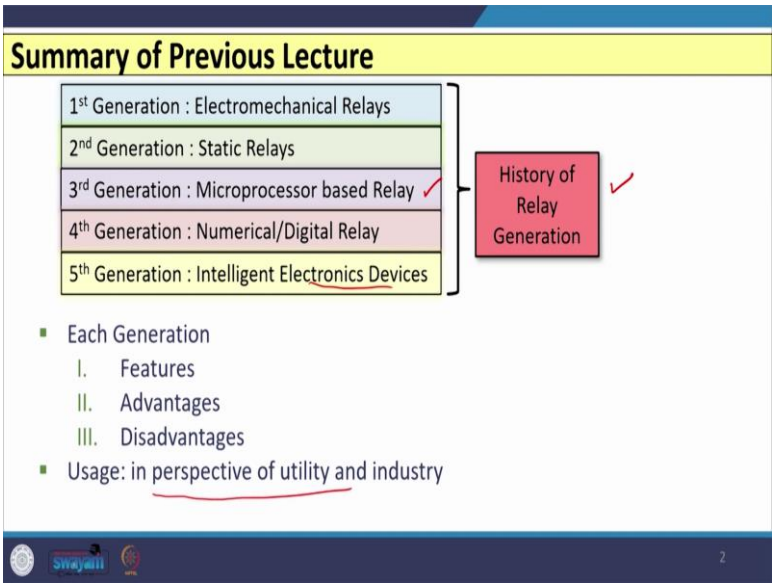

Hello friends. So, in the last class we have discussed regarding the history of generation of relays and in which we have started our discussion with the electromechanical relays. Then we have discussed the relative merits and demerits of electromechanical relays. Then we started discussion about static relays, which contains the electronic components and semiconductor devices.

Then, we have started discussion regarding the microprocessor based relays and digital oblique numerical relays, which are the third and fourth generation of relays respectively and then finally, we have discussed regarding the intelligent electronic devices, which is the latest generation of relays, and widely used by utilities as well as industries. So, we have discussed in IED's, which is intelligent electronic device type of relay, that what is the perspective of the utility as well as industry when such type of relays are used in actual field and practice.

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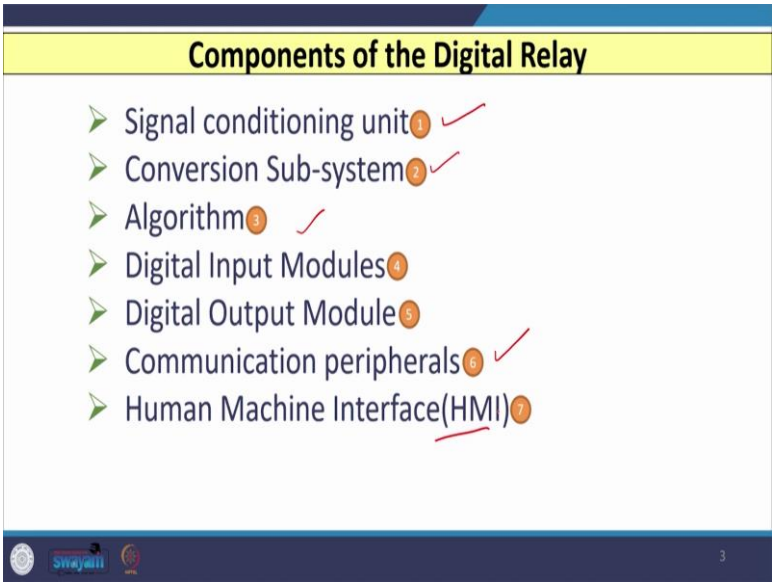

So, in the today's class, we will discuss about the various components of digital relays. So, if we consider the digital or numeric relays, then it contains various components and these components are the first one that is the signal conditioning unit. The second is the conversions sub-system, third is the algorithm.

So, what is the main algorithm which is the core of the digital or numerical relay, then it also contains digital input and digital output modules along with that, it also contains communication peripherals and the human machine interface. So, let us discuss each and every components one by one.

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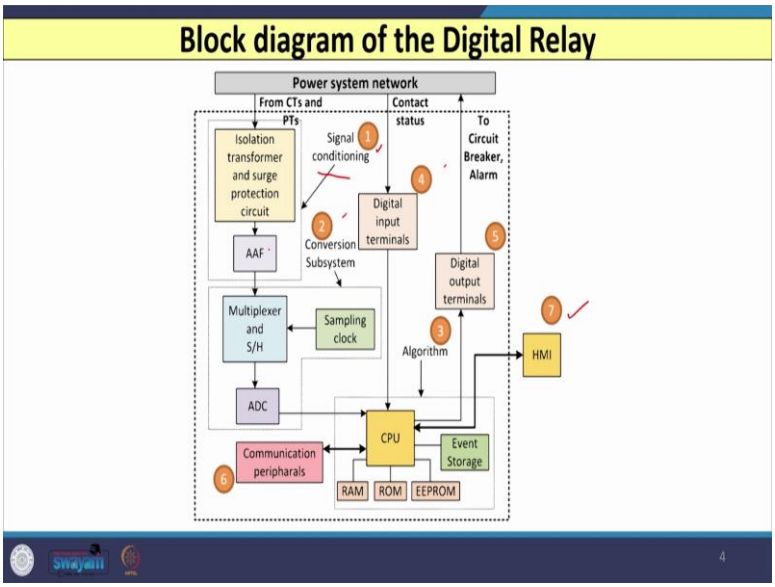

This is the block diagram of digital oblique numerical relays. So, as I listed you earlier the seven components used in the digital relays are given here by 1, 2, 3 up to 7. So, if we consider the first one that is the signal conditioning unit, then signal conditioning unit you can see it contains the two things, one is the isolation transformer and surge protection circuit and second is the anti-aliasing filter that is known as AAF. So, let us discuss first signal conditioning unit.

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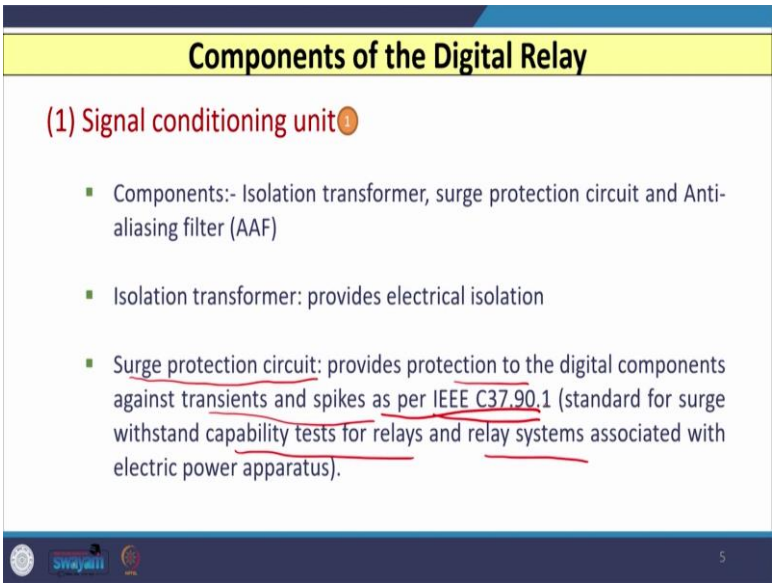

So, signal conditioning unit as I told you it contains two important things one is the isolation transformer and second is the anti-aliasing filters. So, isolation transformer is used just to provide an electrical isolation between power circuit and control circuit. The along with the isolation transformer surge protection circuit is also used in the signal conditioning block.

So, the purpose of surge protection circuit is to provide protection against whatever the digital or electronic components are used in digital and numerical relays against transients and spikes. So, we have discussed that transients and spikes are generated because of lightning surges and switching surges, those surges are travelled through the transmission line and whenever it reaches to the substation, lightning arresters are provided to bypass such surges.

However, if any such surges are still persist, then it should not be available or transferred on the different components used in the digital relay. Otherwise it may damage the components of the digital relay. So, whenever such type of surge protection circuit is provided, this has to be as per IEEE standards and these standards is related for surge withstand capability tests of the relays as well as surge capability tests for various relaying components or systems

associated with electric power systems or apparatus as per this standard surge protection circuit that is provided in the digital or numerical relays.

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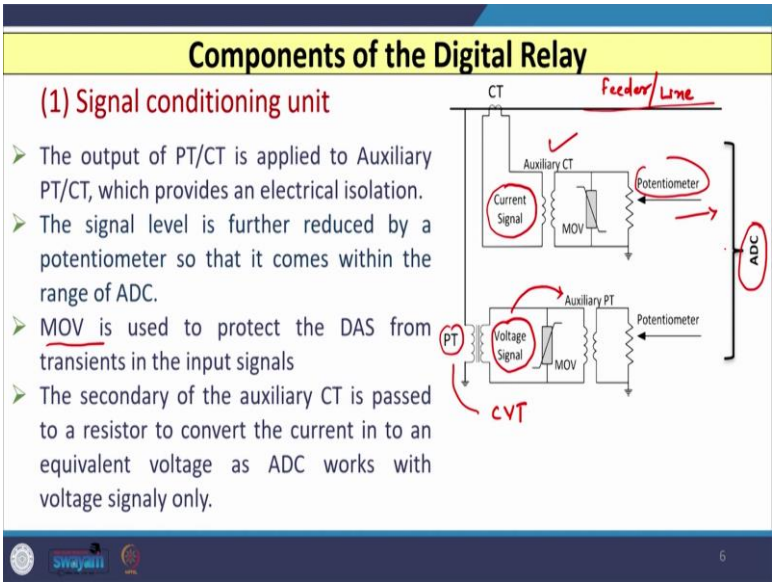

Moreover, when we consider the signal conditioning unit, you can see from this block diagram that we have any line or feeder is there. So, this is your feeder or line and on this feeder we are acquiring the signals from the CT. So, secondary of CT you will get the current signal and we also have PT or sometimes we do have CVT also nowadays.

So, secondary of this PT or CVT, you will get the voltage signal. So, voltage signal is available in a reduced form from the PT as well as secondary of the current signal we will get the reduced form of current and these signals that is CT secondary and PT or CVT secondary, these signals are given to the auxiliary CT if we have current signal and this auxiliary CT is further going to reduce or scale down the current value and then it is connected with the potentiometric arrangement.

So, output of this that is available in the form of voltage. Whatever is the equivalent value of current that will be converted into voltage and that is further given to analogue to digital converter, so, that it can be converted into digital form. Same way in case of voltage signal the auxiliary PT is also provided. So, whatever signal is available here from the secondary of PT or CVT that is given to auxiliary PT and which is further scaled down voltage to a level and so, that that can be directly given to the analogue to digital converters for conversion from analogue signal into digital signals.

Now, in this circuit one very important component is also used that is known as metal oxide varistor. So, MOV is used to protect the data acquisition system from transients and input signals. So, whenever we have any transient is available, then those transients are not going to further available with data acquisition system or ADC otherwise it may damage the ADC.

So, to avoid that we are going to use the MOV. So, another important point is after the conversion of this current signal into lower value and voltage signal into lower value finally, whatever signals we are going to give either from CT or PT we have to give only voltage signal because ADC accept only voltage signal and that is also within certain range.

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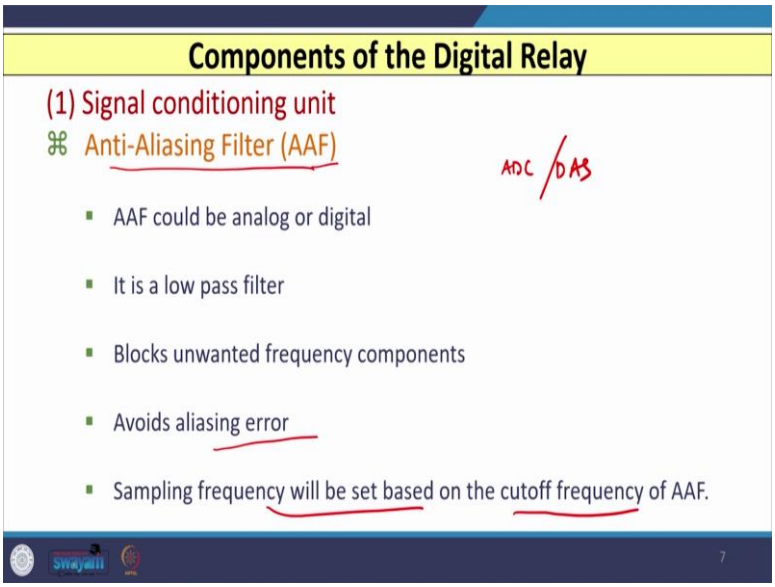

The next component of signal conditioning unit that is known as anti-aliasing filter it is also known as AAF. So, AAF that can be either analogue or digital also and it is normally a low pass filter. So, whenever we acquired means whenever ADC or data acquisition system is going to acquire the voltage or current signal from CT secondary or PT or CVT secondary then those signals also contain harmonics.

So, the function of anti-aliasing filter is to block the unwanted frequency components. So, it is also used to avoid aliasing error we will discuss and whenever such data acquisition is performed maybe voltage or current signal by the ADC or data acquisition system then the sampling frequency is very important and second thing which is very important that is the cut off frequency of the anti-aliasing filter. Normally it should be 150 to 250 hertz we will see later.

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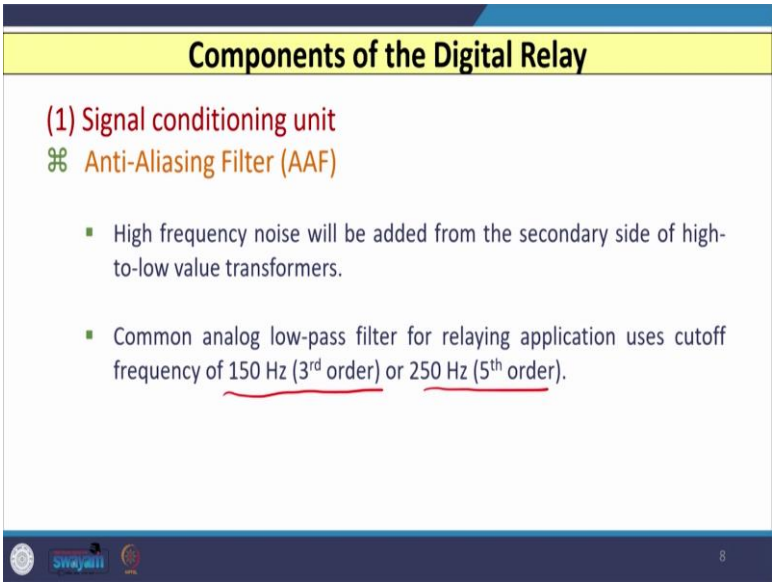

So, whenever we use anti-aliasing filter as I told you noise will be automatically incorporated when we acquire the signal either voltage or current and this noise or unwanted frequency components that can be avoided or blocked by the anti-aliasing filter. So, the for common relaying applications the cut off frequency of this anti-aliasing filter that can be 150 hertz. So, it is 3 times the fundamental component or it can be 5 times the fundamental frequency component that is 250 Hertz.

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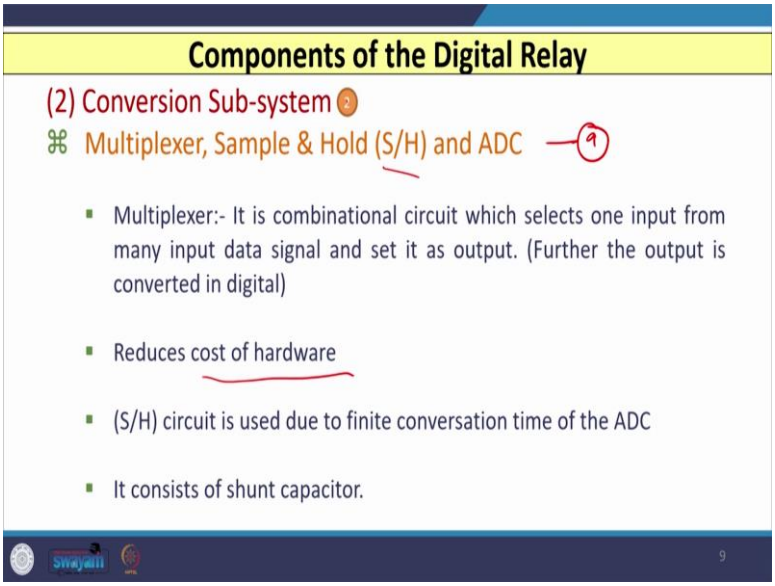

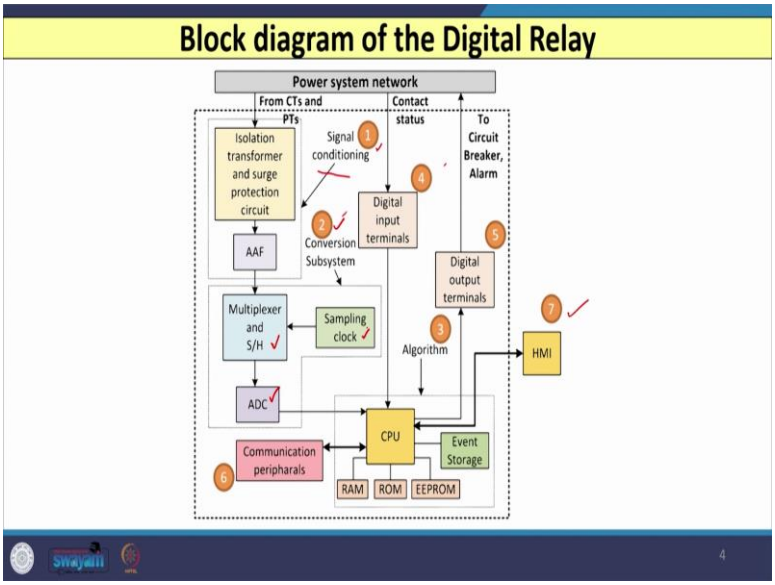

Now, the next block that is nothing but the conversion subsystem block. So, you can see if I refer the conversion subsystem block then again let us come to the block diagram of the digital relay. So, here the second part that is known as convergence sub-system block and convergence sub-system block contains three things. The first is the multiplexer and sample and hold circuit that is this one.

The second is the ADC analogue to digital converters and third that is the sampling clock. So, let us consider each and every component in convergence sub-system block one by one. So, the first thing that is nothing but the multiplexer sample and hold circuits and ADC as I told you it contains.

So, multiplexer is normally a combinational logic block or circuit which selects one input from the available many inputs. It also reduces the cost of hardware that is why we use multiplexer the sample and hold circuit is used to finite the conversion time of the ADC and normally it consist this shunt capacitor.

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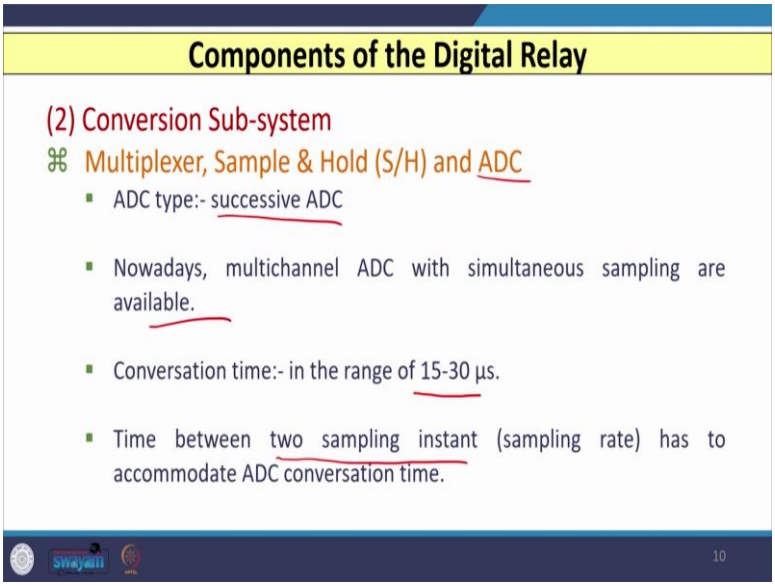

ADC if I consider which is known as analogue to digital converter, so, all the voltages, voltage signals available from CT and PT secondary, those are given to ADC so that it can be converted into digital form. So, normally successive type of ADC that is widely used, however, nowadays multi-channel ADC having a capability of simultaneous sampling that is also used and available.

The conversion time of the ADC that is in the range of 15 to 30 microseconds and whenever we consider these conversion time, we have to also see that the time between two sampling instant that should be accommodated that means your ADC is capable to perform all the calculations within this sampling interval.

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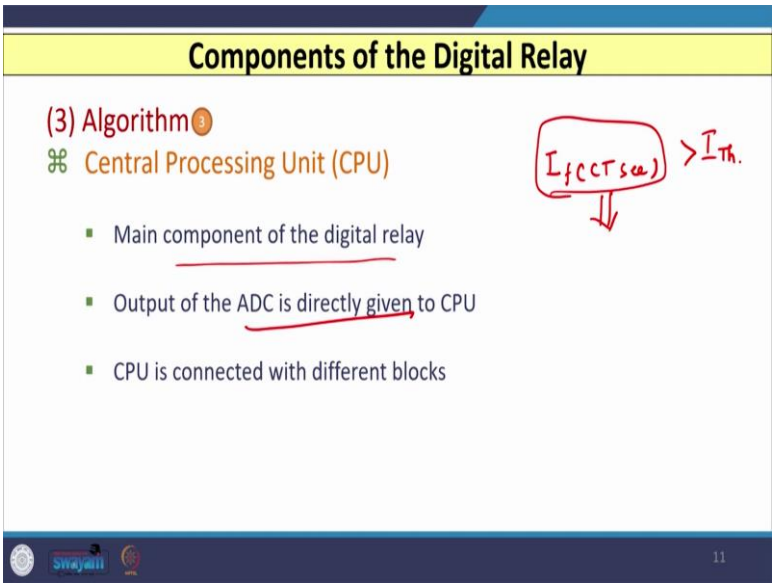

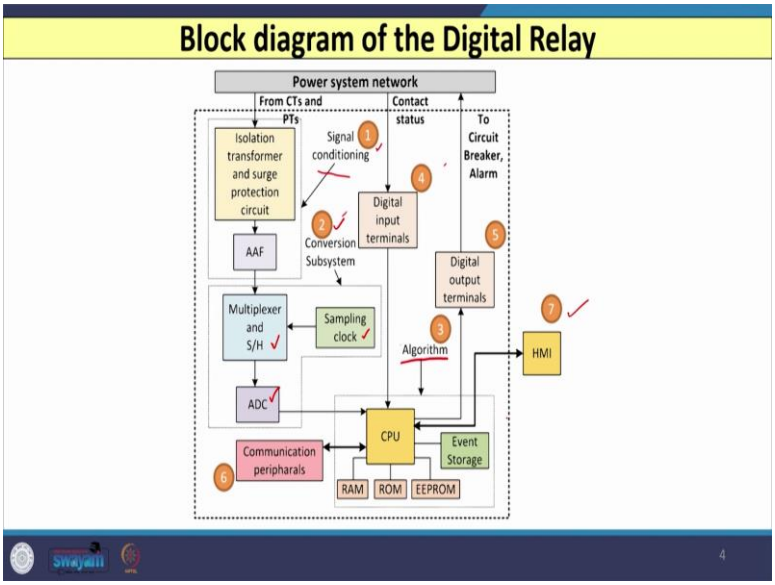

The third subunit of the components of digital or numerical relay that is known as the algorithm. So, again, if I go back to the block diagram of our numerical or digital relay, then you can see the algorithm is available here. So, this algorithm contains again three things one is the central processing unit CPU, second is the event storage and third is the different types of memory devices.

So again, if we consider the algorithm part, then it contains as I told you central processing unit, so which is the main component of relay and whatever algorithm we are going to have for the digital or numerical relay. Let us, say for example, we have a simple overcurrent relay and we want to write down the algorithm for this such that if current or let us say fault current on CT secondary side, if it exceeds some I threshold then relay operates otherwise relay block.

And this I fault CT secondary is let us say some value magnitude part. So, if we want to write such algorithm, then it has to be loaded in the central processing unit. The output of ADC that is also given directly to the central processing unit and CPU is further connected to different blocks of the digital or numerical relay.

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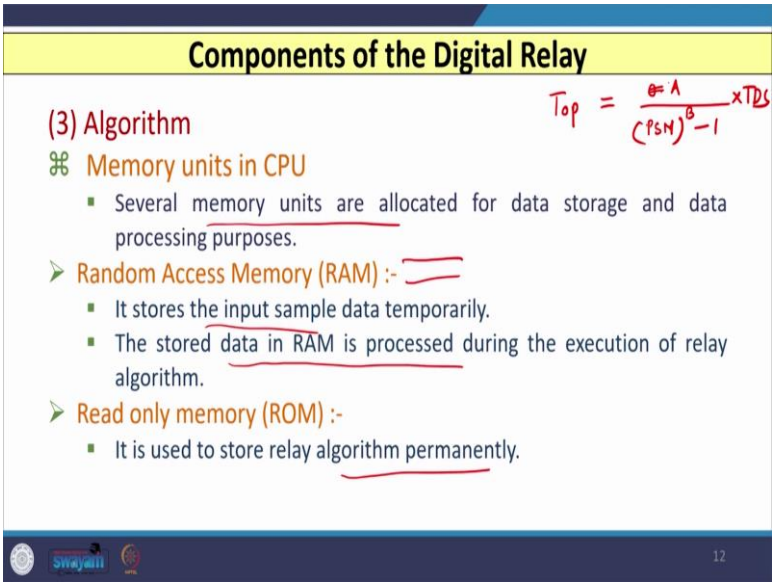

Now, regarding the memory devices, several memory devices are used. The first use is the data storage and data processing purpose. So, we want to store some data, let us say suppose we want to store data's is in the form of let us say some event or fault current or maybe voltages or distance. So, those things we need such type of devices.

Now, if I consider the RAM which is known as random access memory, it stores the input sample data temporarily. So, whenever data acquisition system acquires the current data or voltage data, instant by instant, then those data are stored temporarily in the RAM and whatever processing is required by the relay based on the algorithm, let us say algorithm is going to use let us say six samples in one cycle.

So, six samples are stored in RAM and those samples are utilised by the processor based on the algorithm and further processing is done by the CPU. Moreover, the RAM is also going to store and processed the data during the execution of the algorithm. So, as I told you, if we have simple overcurrent relay, and let us say the equation of this overcurrent relay is given by $T_{op} = \frac{A}{PSM^B - 1} \times TDS$. So the function of read only memory is to store the relay algorithm permanently. So, whatever relay algorithms are there, that is going to store in the this read only memory.

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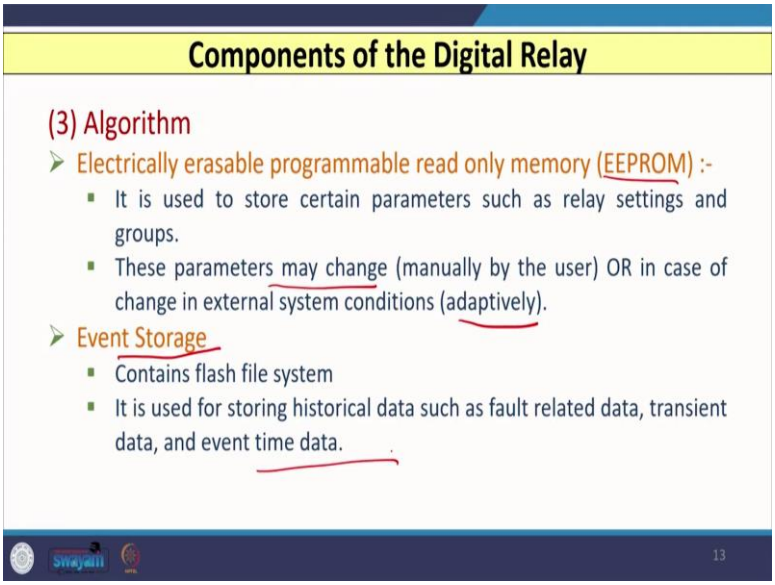

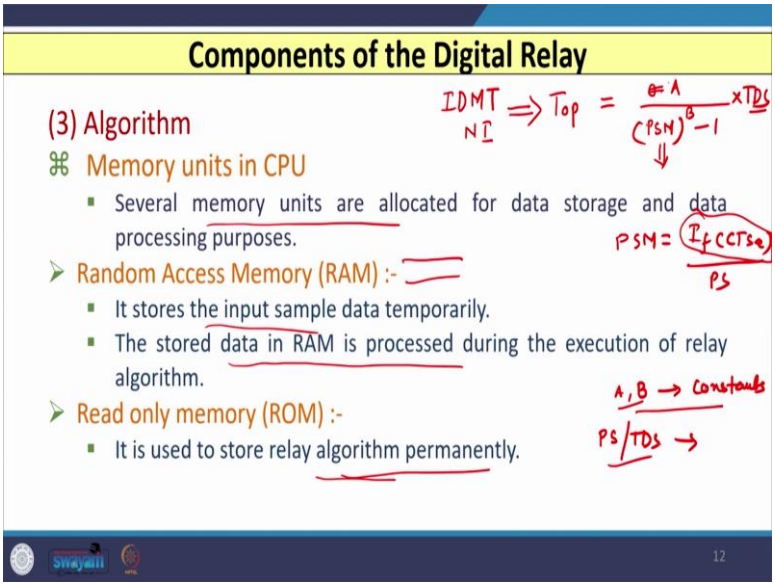

And the another memory device is also available that is EEPROM that is electrically erasable programmable read only memory. So, it is used to store certain parameters, let us say the relaying parameters and characteristics, those things are stored in the EEPROM. Now, if I have let us say simple IDMT, that is inverse definite minimum time over current relay having normal inverse characteristic and its equation is given by this.

So, time of operation of this relay is given by this where A and B these two are constant. So, it is already defined by the manufacturer and these constants are already stored in the EEPROM because for normal inverse characteristic, these constants are used and they are not going to change at all.

So, these are there in the EEPROM, then we have the plug setting multiplier. So, plug setting multiplier is defined by fault current available on CT secondary divided by plug setting of the

relay. So, plug settings the range of plug settings are available similarly range of TDS are available and these values are already PS and TDS these values are already available or stored in EEPROM.

So, now what is required is the algorithm is again given or return in the ROM your data which are going to acquire by data acquisition system in terms of here let us say current, because you need fault current here this thing. So, these are stored temporarily in RAM and other parameters like plug setting, time dial setting, characteristic constants, all those are stored in EEPROM.

So, whenever sufficient data are available, then your central processing unit will run the algorithm available in the ROM it utilises the data from the RAM that is the fault current data, maybe samples of fault current data and it also utilises all these constants and setting parameters, those are stored in the EEPROM and then finally run the algorithm and then whatever is the output of that algorithm that will be available.

Moreover, in EEPROM the parameters that is relay settings, plug settings, time dial settings manually, it can be changed by any person or engineer working in the utility. Let us, say I want to change these parameters from X value to Y value. So, it can be changed or if any external system condition changes, then it can be changed adaptively also this is also possible, then we have event storage block.

So, this contains flash file system and normally it is used to store the historical data, let us say we want to store the fault current data of all the three phases RYB, let us say we want to stored or find out what are the harmonics are present at what instant transients is available, what is the inception of time of fault, so all those things are stored in the event storage block.

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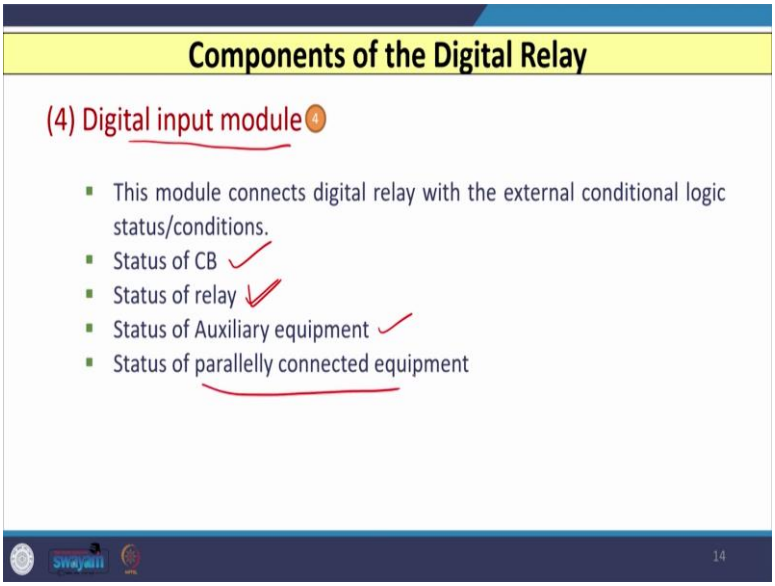

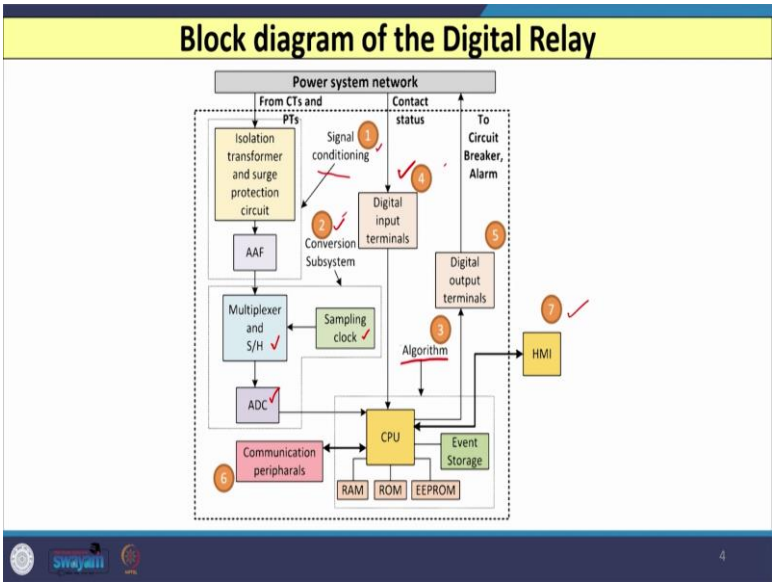

Now, the fourth module of the digital or numerical relay that is digital input module. So, this module, if I go further, if you see the block diagram of digital relay, then you can see that here the digital input modules are available here. So, this digital input terminals or modules will take input from the power system network and it is given to the central processing unit in the algorithm part.

So, if we further go and see the digital input module block, then this module is going to connect digital relay as I told you with external system devices or conditions. This digital input module will acquire the status of the circuit breaker if any external circuit breaker is there, it will also acquire status of the relay, let us say some remote relay in an interconnected

network or system, let us, say 8 relays are there and we need status of other 7 relays. Then those are also acquired by digital input module.

We let us say we want the status of some auxiliary equipment. Let us, say we want we have a transformer and we want status of let us say temperature of the winding or oil level indicator status. So, those are also acquired by this digital input module and status of any parallelly connected equipment that is also acquired by digital input module.

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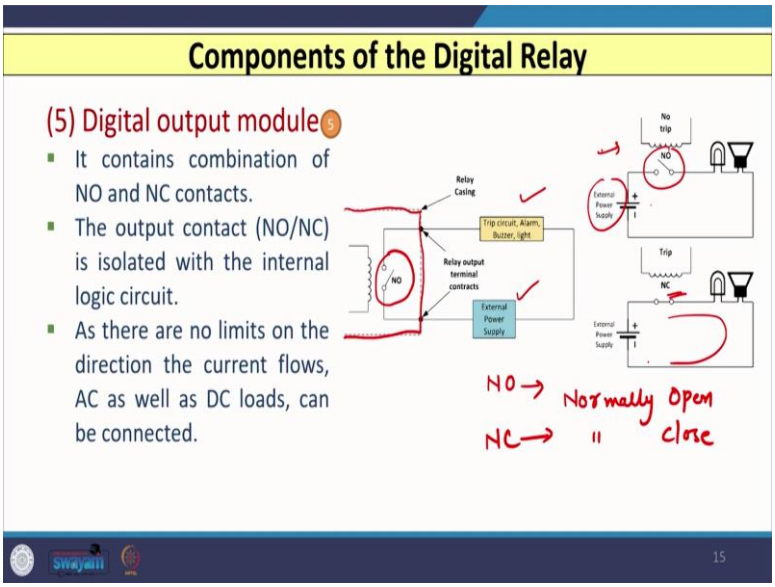

Now, the next block that is known as digital output module. So, digital output module contains several normally open and normally closed contacts. So, these contacts you can see here I have shown one diagram where this is nothing but your relay case and I have shown one normally open contact, NO contact which is known as normally open contact. Similarly, you have NC contact also which is known as normally close contact.

So, whenever any tripping command is initiated then this normally open contact will close means its status is changed and normally open contact that becomes close and whenever this circuit is closed then any tripping circuit or alarm or buzzer that will be initiated. Now, whenever we use such type of normally open or normally closed contact then you can see I have also shown here we have one normally open contact in normal condition when no trip is initiated, we need external power supply also. So, it is also available here, but this circuit is not completed.

Below this thing I have shown that whenever some tripping command is initiated your normally open contacts that become close here. So, this circuit is completed and maybe

whatever alarm or indication you need that is available or displayed and operator will know that something is going to happen. So, operator can take appropriate action depending upon the severity of the nature of the condition.

So, this is also very important point and see there are no limits as far as the direction of current is concerned. So, you can use either AC or DC type of loads you can connect here with these contacts. So, you can connect either AC circuit or DC circuit with this NO or NC contacts.

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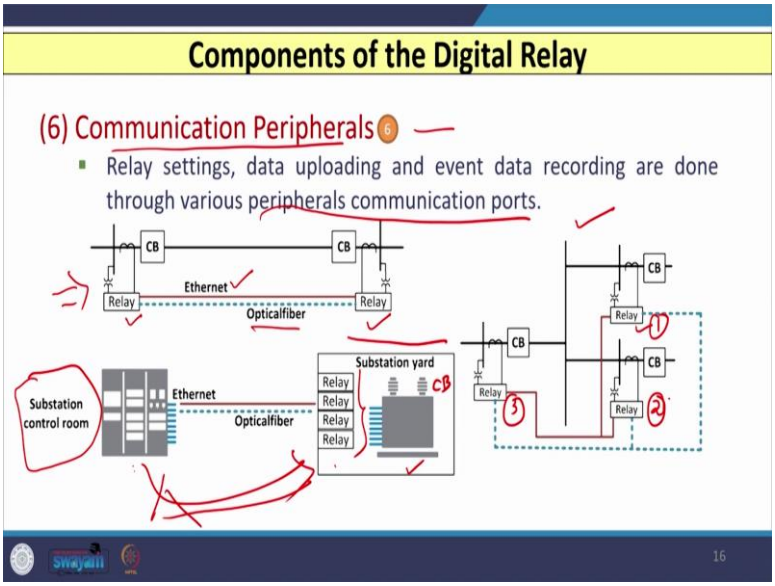

The next component is the communication peripherals. So, you can refer the block diagram of the relay or digital or numerical relay, then it contains communication peripherals. So, when we have relay settings, when we want to upload the data and when we want to record some data, maybe for monitoring purpose, then those for those three these three important things we need several communication ports and peripherals.

For example, if one relay here you can see here, if I want to communicate this relay with the relay located at the far end then the one of the way of communication is we have either Ethernet or we have optical fibres. Similarly, if I if one relay in the substation wants to communicate with other relay let us say this relay 1 wants communication with relate 2 and really 3 then it can be done through either Ethernet or optical fibre.

Similarly, if I have some substation control room and if I have some substation yard where number of relays are there, you can see and circuit breaker is also there, this is your circuit

breaker let us say and if you wish to communicate from this substation control room with these things, then it can be done through either this communication ports or peripherals.

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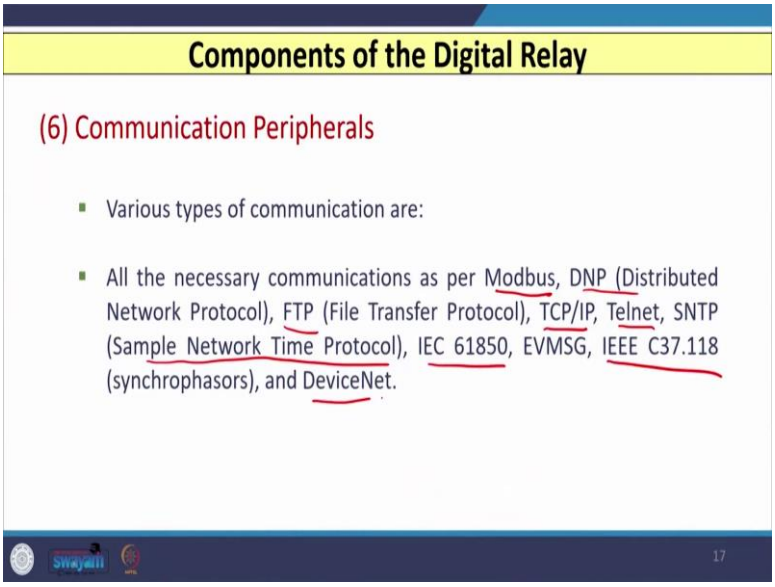

So, different types of communication are possible and this are Modbus type of communication. Maybe distributed network protocol is also there, file transfer protocol is also there, TCP IP that is transmission control protocol and internet protocol is also there, telnet is also their sample network time protocol is also there known as SNTP and IEC 61850 and IEEE C37.118, which is used in synchrophasors work for PMU this is also there, along with device net type of protocols.

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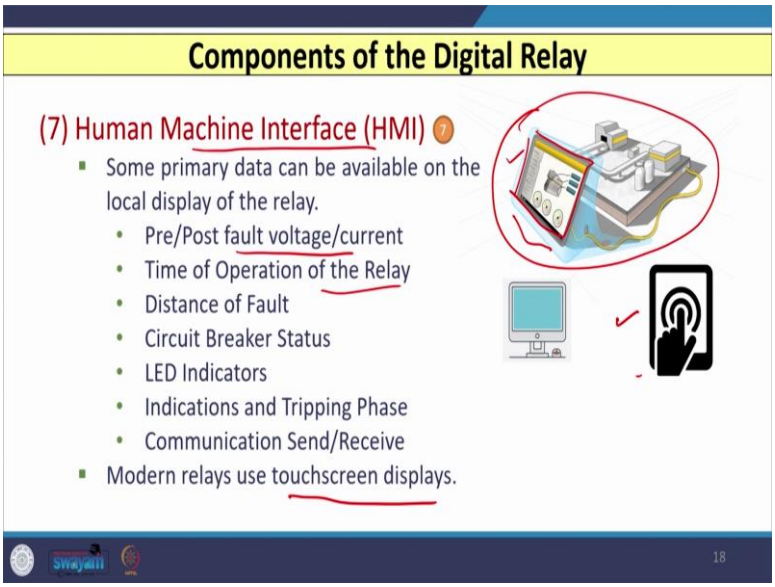

The last unit of these components of digital or numerical relay is the human machine interface also known as HMI. So, you can see that the some of the primary data that can be available on the local display of the relay and this data are maybe you have post fault current and voltage even pre fault also. Time of operation of the relay, distance to fault, status of circuit breakers, maybe status of some indicators are also there, whether you have received some communication from the other end or not. So, status of that is also there.

So, most of the modern relays as I told you that the latest generation of modern relays use IDs. So, they have touchscreen displays even you have some keys also and you can also use that keys but nowadays limited keys are provided and maybe you have you can see here you have some substation also and you may have human machine interface of this different parts of the substation considering this as a substation and you can have some interface that is also possible.

So, in this class we have discussed with the different components of numerical or digital relays. So, we have seen that there are various units or components of digital relays and we started with the first that is signal conditioning block, then we have discussed convergence of system block then we have discussed algorithm part, then we have discussed digital input and digital output modules and then we have discussed communication peripherals along with the human machine interface and we have also discussed why this all these sub components, which are there inside the digital or numerical relays are very important. So, those things also we have discussed. Thank you.